Forestry and the Carbon Offset Conundrum

G Cornelis van Kooten, PhD, FRSC

Outline

1. Research and preliminaries
2. Carbon offset markets: Theory
3. Climate change and forest carbon offsets
4. Rotation ages and carbon offsets
5. Politics and corruption

1. Research Landscape: Key Findings

Source: *State of Carbon Dioxide Removal* report (2023)

- Vast and fast-growing scientific literature on Carbon Dioxide Removal (CDR) of about 28,000 studies in Web of Science and Scopus alone – two of the largest English-language bibliographic databases.
- Studies on CDR make up <4% of the scientific literature on climate change but growing exponentially by ≈19% per year (1990-2021). Annual publications double every three to four years.
- Scientific studies on CDR dominated by biochar, soil carbon sequestration & afforestation/reforestation, accounting for ≈80% of CDR methods in literature.
- Research on biochar is growing faster than that of any other CDR method, accounting for ≈40% of the coverage on CDR methods in the scientific literature overall and ≈50% of the studies published in 2021.

Research Landscape: Key Findings (cont)

- Bioenergy with Carbon Capture and Storage (BECCS), as well as Direct Air Capture with CCS, receive comparatively little attention in the CDR literature – despite dominating discussions on the role of CDR in climate change mitigation scenarios and private CDR investment.
- Only about a third of the scientific literature on CDR has a geographical focus, highlighting a potential lack of information tailored to specific local or regional contexts, particularly Africa and South America.
- Based on first author affiliation, 32% of scientific studies on CDR are written in China, 9% in the United States and 4% in Australia. This is particularly driven by a strong dominance of biochar research in China.

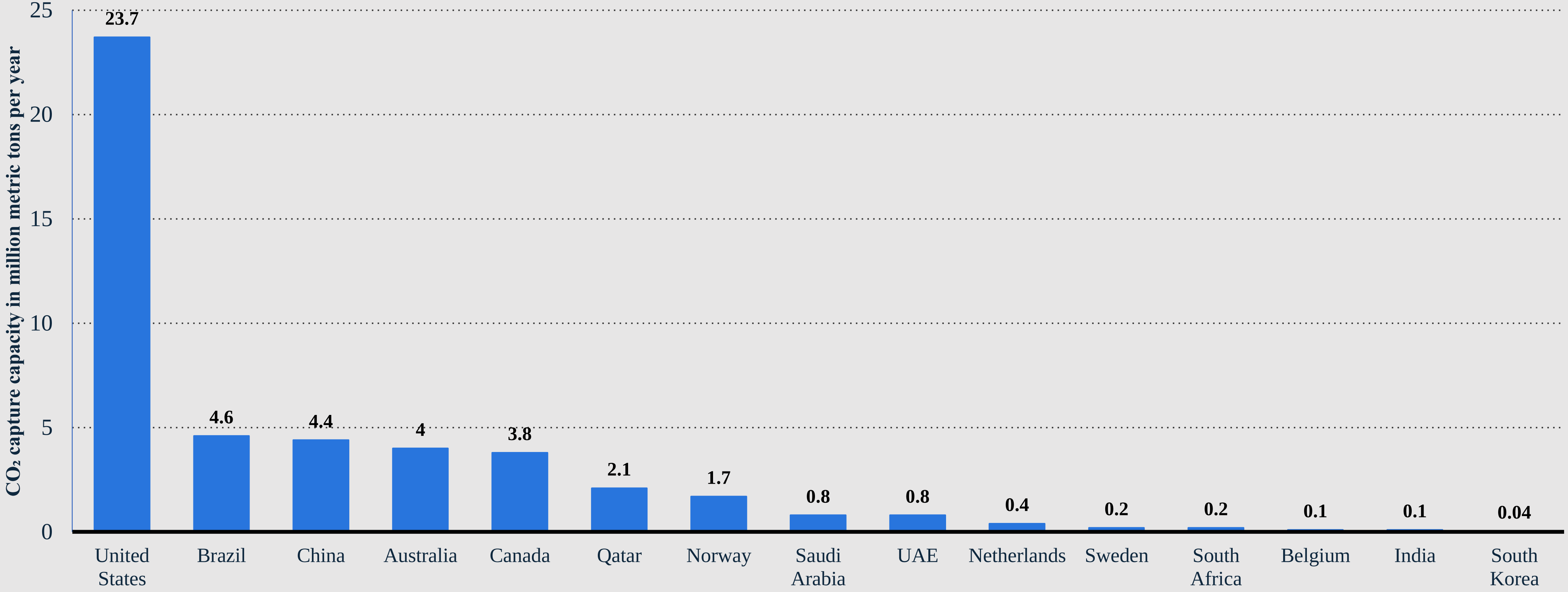
Research Landscape: Key Findings (cont)

- The scientific literature on CDR is mainly published in natural science (49%), agricultural science (25%) and engineering and technology journals (23%). Only 3% is published in social science journals, and a handful in the humanities.
- Policymakers' focus to date has been on conventional CDR on land, through forestry and agriculture. However, attention on BECCS, Direct Air CCS and other novel CDR methods (not identified) is increasing.
- **Conclusion**: Afforestation/forestation along with, perhaps, BECCS are currently considered of utmost importance in achieving climate mitigation targets!

Capacity of operational carbon capture and storage (CCS) facilities worldwide as of 2022, by country (million metric tons per year)

Global CO_2 capture capacity worldwide 2022. by country

IEA data for 2022:
Canadian emissions: 511.6 Mt CO2/yr (0.7%)
US emissions: 4,549.6 Mt CO2/yr (0.5%)



Note(s): Worldwide; 2022; Excludes storage projects
Source(s): IEA; IHS Markit; S&P Global; ID 1411879

statista

Preliminaries

“Today’s IPCC Working Group 1 report is a code red for humanity. The alarm bells are deafening, and the evidence is irrefutable: greenhouse-gas emissions from fossil-fuel burning and deforestation are choking our planet and putting billions of people at immediate risk” (United Nations 2021).

Simon Stiell, Executive Secretary of the United Nations Framework Convention on Climate Change said the next two years are "essential in saving our planet“ (Reuters, April 10, 2024)

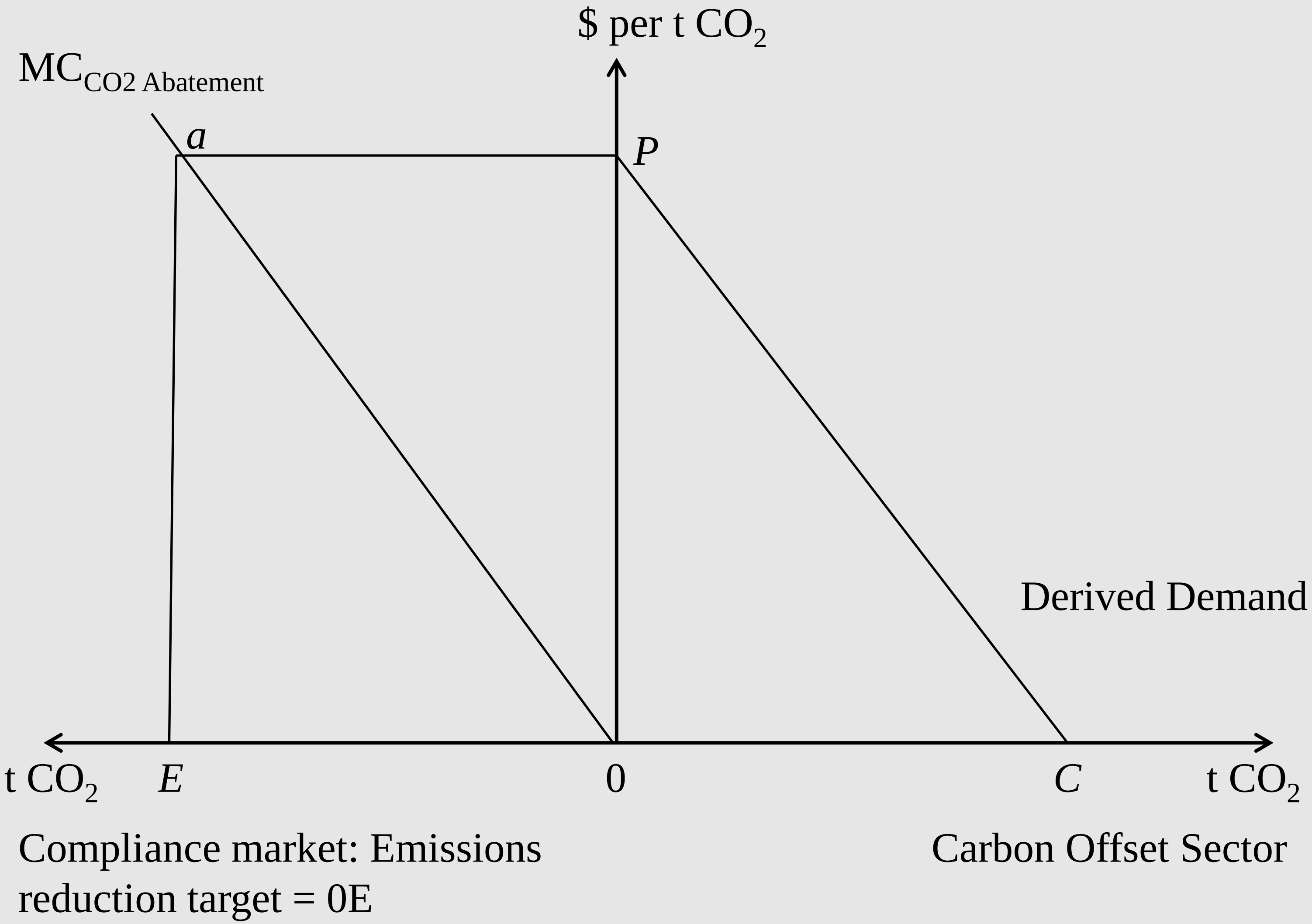
“The United Nations (UN) Intergovernmental panel on Climate Change (IPCC) has recently published a report (abbreviated as SR15) which concludes that humankind has a mere 12 years left” to address climate change (Rhodes et al. 2019, *Science Progress* 102(1):73-87).

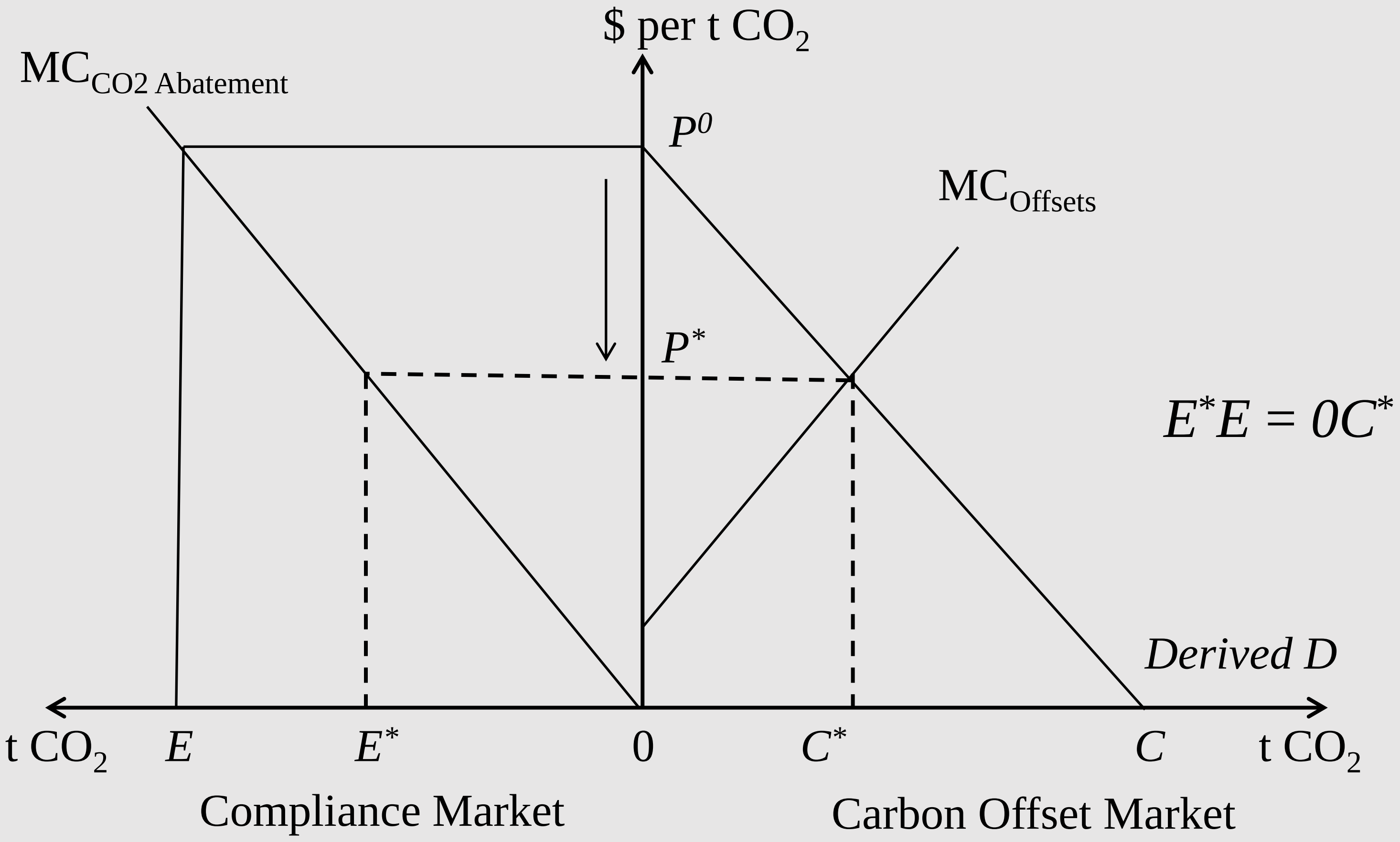
Implication: Terrestrial carbon sequestration is too late!?!

- Terrestrial carbon fluxes are a problem when it comes to carbon dioxide removals (CDRs)
  - Timing of future carbon fluxes/values is an important issue in deciding whether there is any value to the temporary storage of carbon
    - Economists prefer use of social rate of time preference (Ramsey formula), which is low to account for future generations. But it favors delay of carbon uptake
    - Weighting future CDRs much less than current ones (because climate mitigation is urgent) implies high rate used to discount future carbon
    - Social rate of time preference and rate used to discount carbon values are in tension as they deal with two different issues.
  - Open to corruption
  - Counting emission reductions from activities that prevent GHG emissions are particularly problematic (e.g., deforestation, prevention of tillage operations)
- Countries are less interested in preventing climate change, but are interested in virtue signaling—“we have done our part, now do yours”

2. Carbon Offset Markets

- Carbon offset: a reduction in CO_2 emissions, or an equivalent removal of CO_2 from the atmosphere, that is realized outside a *compliance market* and can be used to counterbalance greenhouse gas emissions from a capped entity. Referred to as carbon dioxide removals (CDR)
- Martin Weitzman's "Prices vs Quantities" (tax vs cap-and-trade) favours a carbon tax over carbon trading simply because the costs of achieving a cap are unknown.
- BUT countries do everything against the recommendations of economists, imposing a tax, implementing a carbon market, and mandating a variety of programs (e.g., EV targets, forcing forest companies to remove and use roadside waste, restrict fertilizer use) that should be incentivized by the price on carbon
  - Canada has 147 programs in place, including the tax


$ per t CO_2
$MC_{CO2\ Abatement}$
a
P
Derived Demand
t CO_2
E
0
C
t CO_2
Compliance market: Emissions reduction target = 0E
Carbon Offset Sector



Carbon offsets (i) reduce emitters’ costs of complying with emission reduction targets, (ii) buy time to develop & adopt emission-reducing technologies, but (iii) reduce incentives to invest in such technologies while (iv) increasing uncertainty and corruption.

van Kooten and de Vries (2014); van Kooten et al. (2015)

Problems with offsets

1. *Additionality*: criterion dictating that an emission source can only obtain carbon offsets for emission reductions above and beyond what would occur in the absence of carbon offset incentives

2. *Leakage*: the extent to which a climate mitigation activity in a certain location increases CO_2 emissions elsewhere.

3. *Double dipping*: selling multiple environmental services, such as carbon offsets, in more than one market (e.g., Annex B country invests in tree planting project in China, with both countries claiming carbon reduction benefits)

4. *Plethora of instruments*: instruments available to Annex B countries (lack of commensurability → duration problem):

   1. reduce domestic CO_2 emissions,
   2. purchase allowances from other Annex B countries (whose emissions are below target),
   3. sequester carbon in domestic biological sinks,
   4. purchase certified emission reduction credits (CERs) via CDM,
   5. earn reduction units (ERUs = CERs) in economies in transition via Joint Implementation mechanism.

   CERs could also be earned for CO_2 removed from the atmosphere by afforestation/reforestation

Problems (cont)

5. *Duration*: the length of time that an activity to mitigate climate change keeps CO_2 out of the atmosphere. For removal projects, this is the time between CO_2 uptake and eventual release; it is also the time between emissions reduction and the eventual release of carbon in the ‘saved’ fossil fuels, although this period is often taken to be infinite. van Kooten et al. (2021); van Kooten (2023, 2024)
6. *Transaction costs and governance*: costs of measuring, monitoring, enforcing and negotiating trades, and how trades are made. van Kooten (2017)

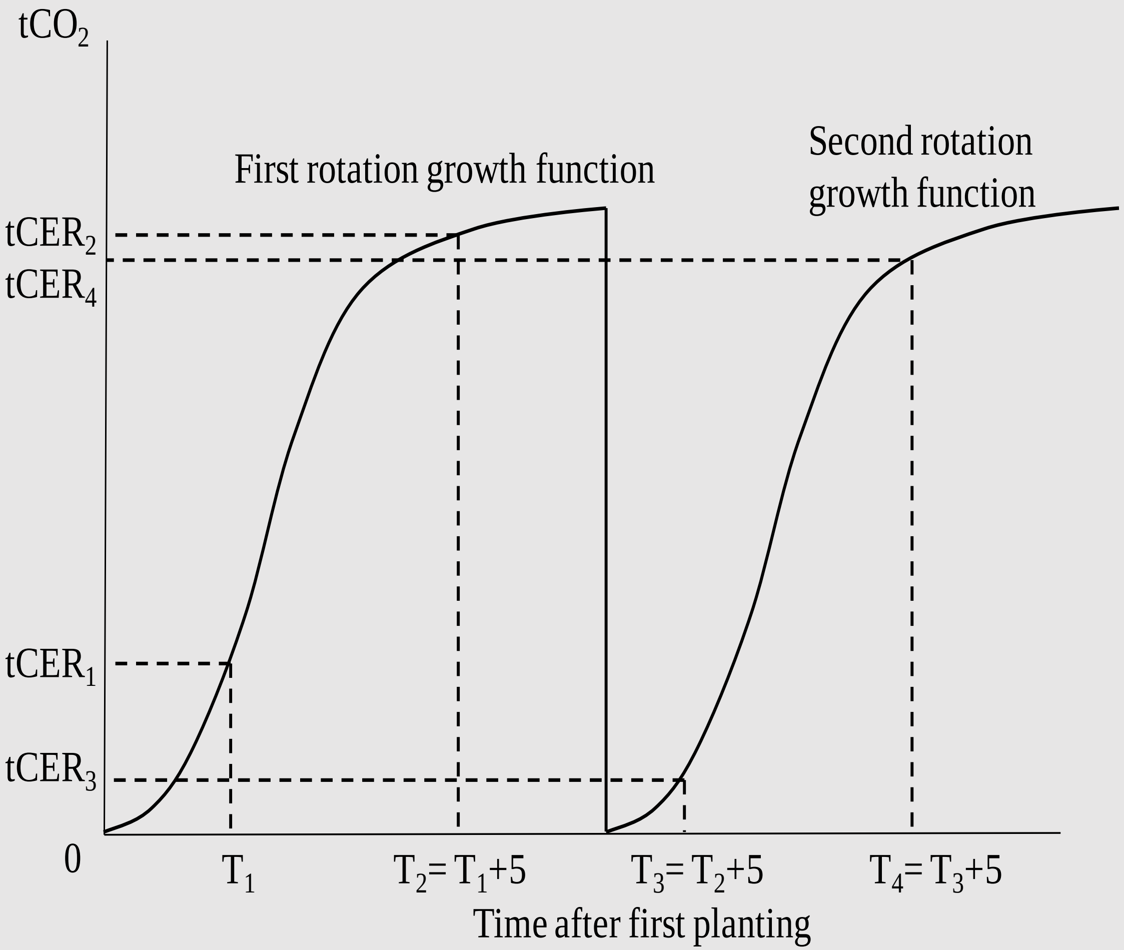
3. Climate Change and Forest Carbon Offsets

- Forest carbon offsets plagued with measurement problems (leading to corruption)
  - Arbitrary cutoffs for determining carbon uptake (sequestration)
  - Issue of temporary (5-year) offset permits vs long-term offsets

tCER—temporary certified emission reduction (annual rental)

lCER—long-term but not permanent (5-yr)

Kyoto Process Solution to Incommensurability Problem: Defining lCERs and tCERs from Forestry Activities



$$\text{lCER} = \text{tCER}_2 - \text{tCER}_1,$$

or

$$\text{lCER} = \text{tCER}_4 - \text{tCER}_3$$

Release of CO_2 from harvesting ignored.

Source: van Kooten (2013, pp.355-358)

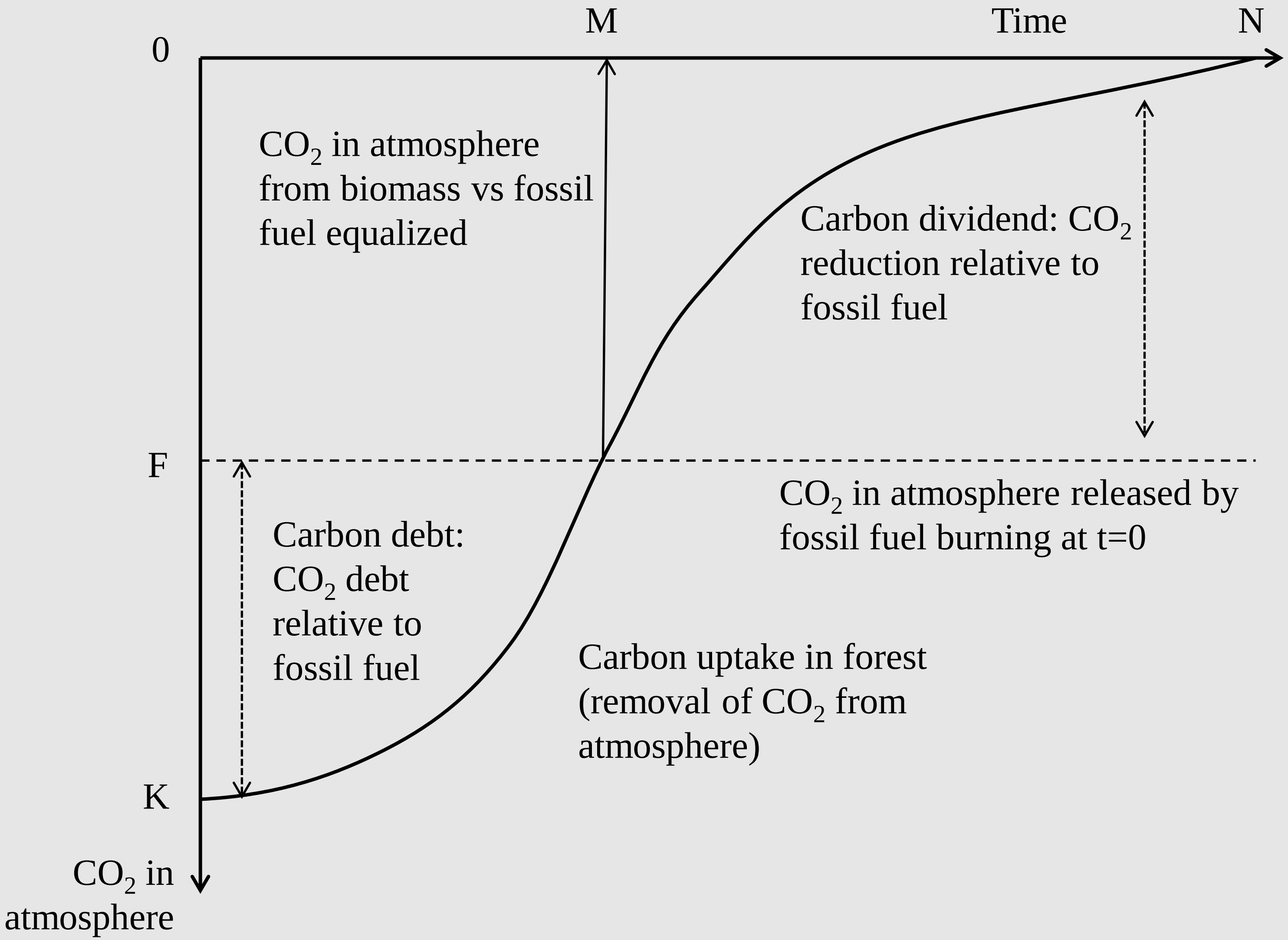
What affects measurement of forest carbon offsets, or carbon dioxide removal (CDR)?

1. Weighting of carbon dioxide as to when the carbon flux occurs (i.e., different social and carbon discount factors)
   - Important policy variable
   - Recognizes whether addressing climate change is urgent
2. Decay of post-harvest wood product and ecosystem carbon pools.
   - Enables calculation of CDR over all time
   - Determined by physical attributes of carbon pools
3. Other factors:
   - Type of tree species and variety (e.g., genetically modified)
   - Location and quality of the forestland
   - Management (e.g., forest rotation age, harvest method)
   - Natural disturbance (viz., wildfire, MPB)

- Given planting, one cannot ignore the impact of harvests and alternatives:
  - Never harvest: ‘Conservation’
  - Store carbon in products and, when wood substitutes for concrete/steel in construction, count emissions avoided because these materials are not produced
  - Use biomass for fuel (increasingly popular) – see next slide
- How urgent is need to stop global warming?
  - Low urgency → 0% discount rate on carbon values
  - Great urgency → high discount rate on carbon

Weighting Carbon as to When it Occurs:

Cumulative carbon (tCO_2): fossil fuel vs biomass sources for generating electricity



CO_2 in atmosphere from biomass vs fossil fuel equalized

Carbon dividend: CO_2 reduction relative to fossil fuel

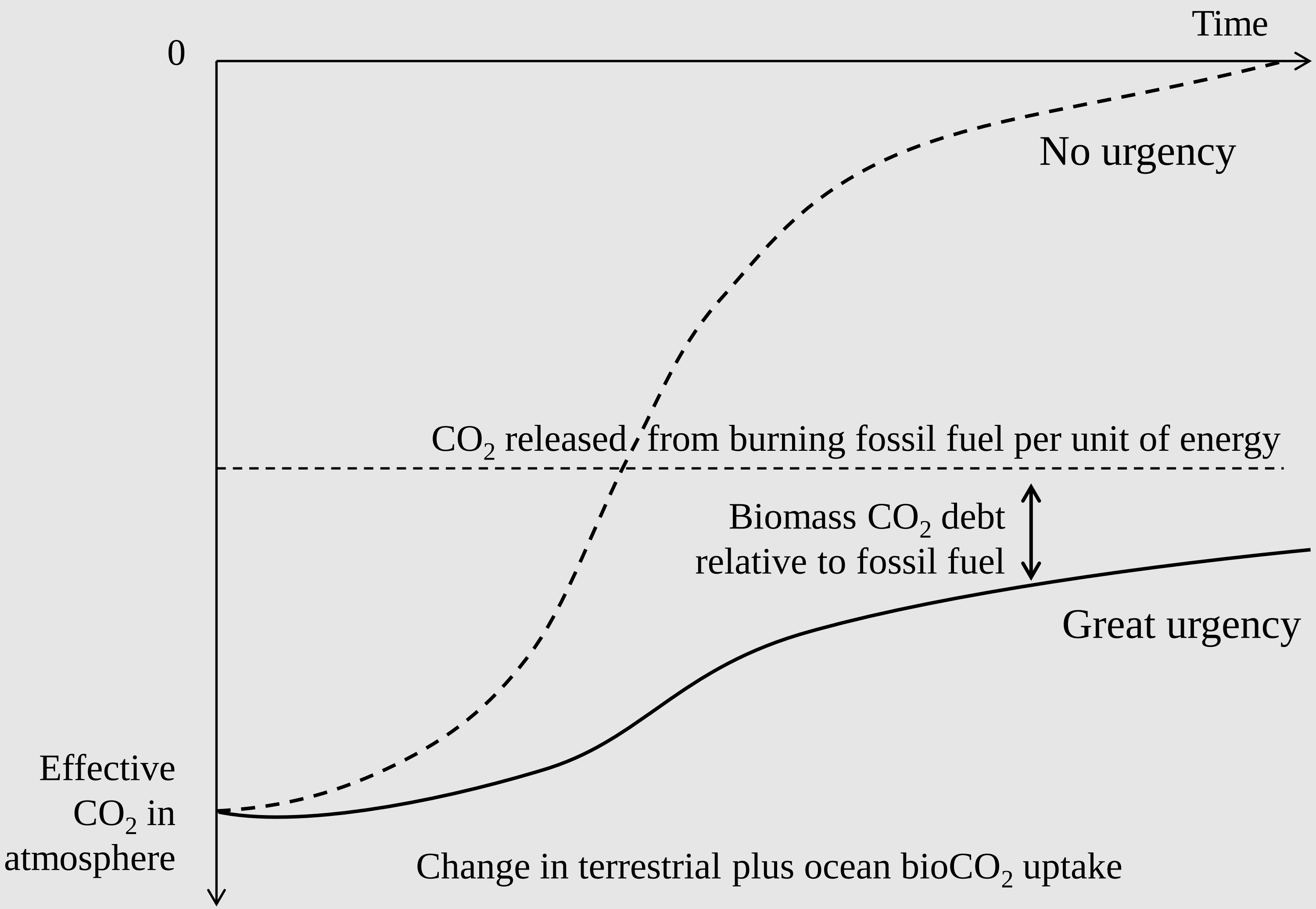
CO_2 in atmosphere released by fossil fuel burning at t=0

Carbon debt: CO_2 debt relative to fossil fuel

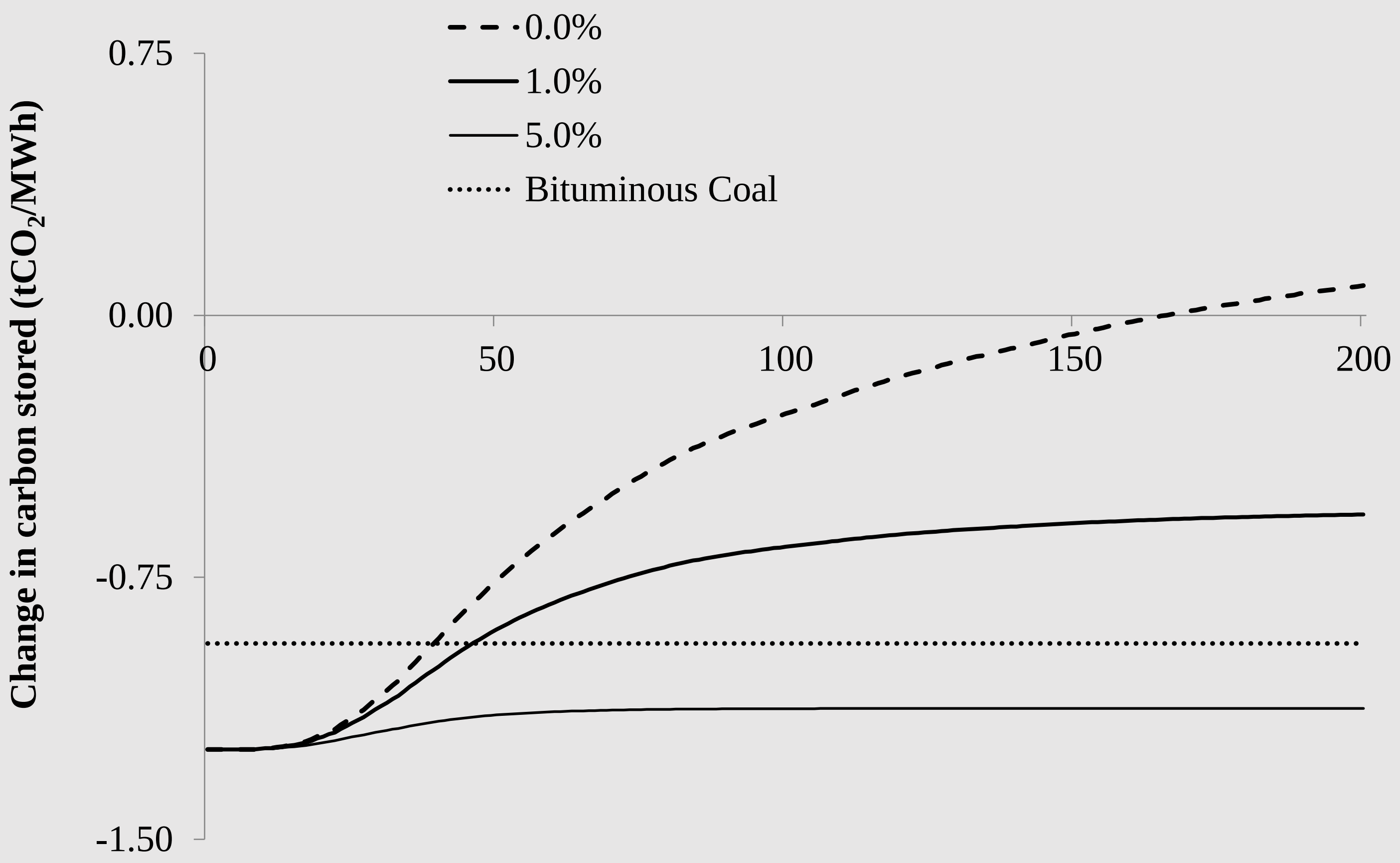
Carbon uptake in forest (removal of CO_2 from atmosphere)

CO_2 in atmosphere

Carbon neutrality? If there is no urgency to address climate change, future and current emissions/uptake are identical. If there is urgency, current emissions/uptake weigh more heavily than future ones.



Lodgepole pine (*pinus contorta*)



Projected volume (m^3 ha^{-1}) in Dawson Creek forest of Prince George district with average slope of 10% & initial density of 1,600 trees ha^{-1}

4. Rotation Ages and Carbon Offsets

Two approaches used to address economic issues of commercial plus CDR benefits of forestry activities

1. Timber management models that include commercial timber values and carbon prices
    - E.g., Darkwoods analysis demonstrates the importance of a baseline BAU (*Forest Science* April 2015)
2. Forest rotation models are generally preferred by economists

Type of Rotation	**Formula to Determine Rotation Age**
Single cut	$\frac{v'(t)}{v(t)} = \delta$
Faustmann (financial) rotation	$\frac{v'(t)}{v(t)} = \frac{\delta}{1 - e^{-\delta t}}$
Hartman rotation	$\frac{[P_F + \mu(t)]\frac{v'(t)}{v(t)}}{P_F + \int_0^t \mu(s) e^{-\delta s} ds} = \frac{\delta}{1 - e^{-\delta t}}$

$v(t)$ = volume of timber at time t (m^3); $\mu(t)$ = non-timber (environmental) benefits at time t; P_F = price of timber (\$/m^3); P_c = price of carbon (\$/tCO$_2$); α = tCO$_2$/m^3; δ = monetary rate of discount

Carbon rotation

- Formula for calculating rotation age for variety of parameters indicated on previous slide (modified Hartman rotation to include carbon)

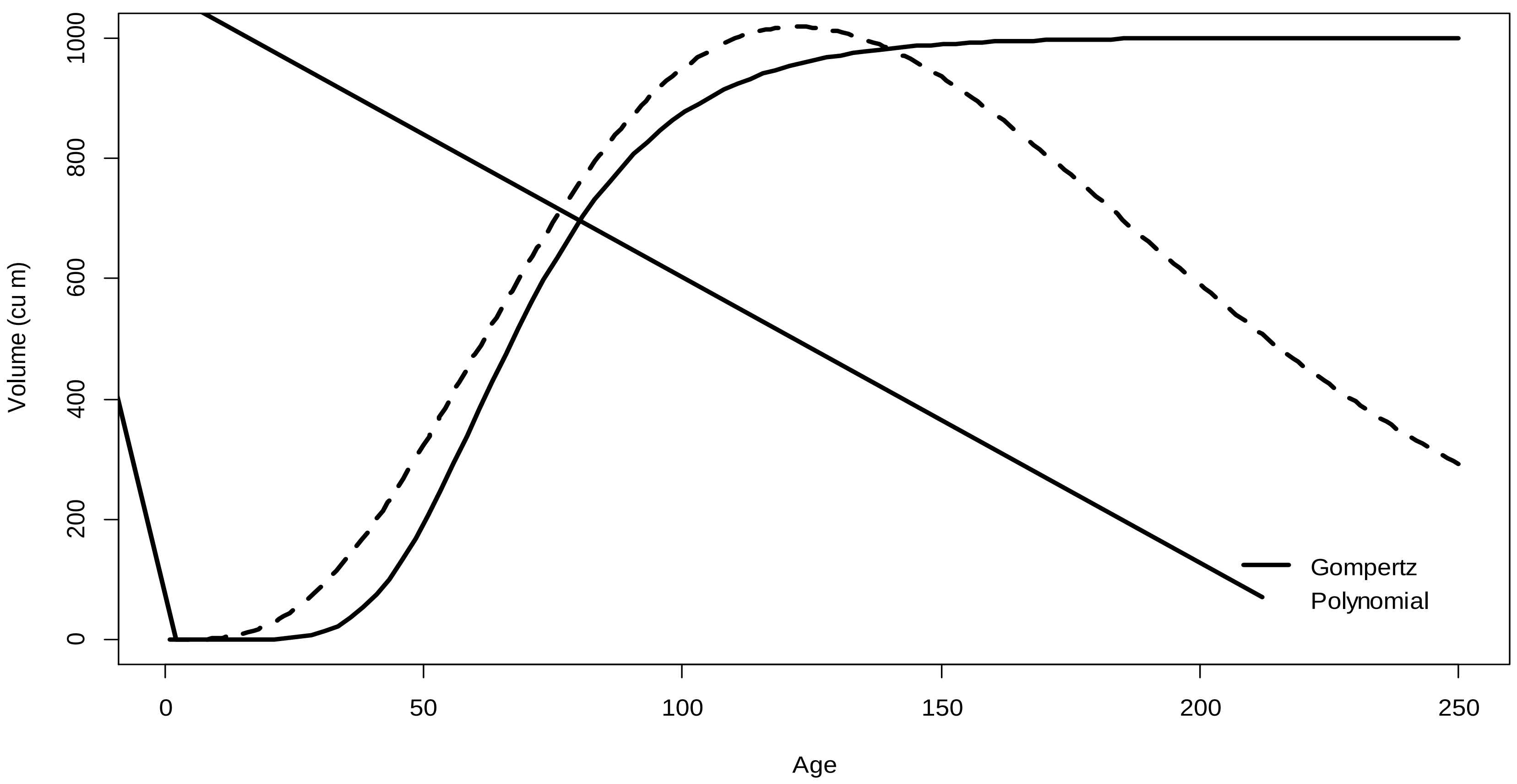
$$\frac{(P_F + Ae^{-\gamma t})\frac{v'(t)}{v(t)} + [\alpha P_c(\delta + \gamma) - \gamma A]e^{-\gamma t}}{(P_F + A) + \frac{\alpha P_c(\delta + \gamma)}{v(t)}\int_0^t v(s)e^{-(\delta+\gamma)s}ds} = \frac{\delta}{1 - e^{-\delta t}}$$

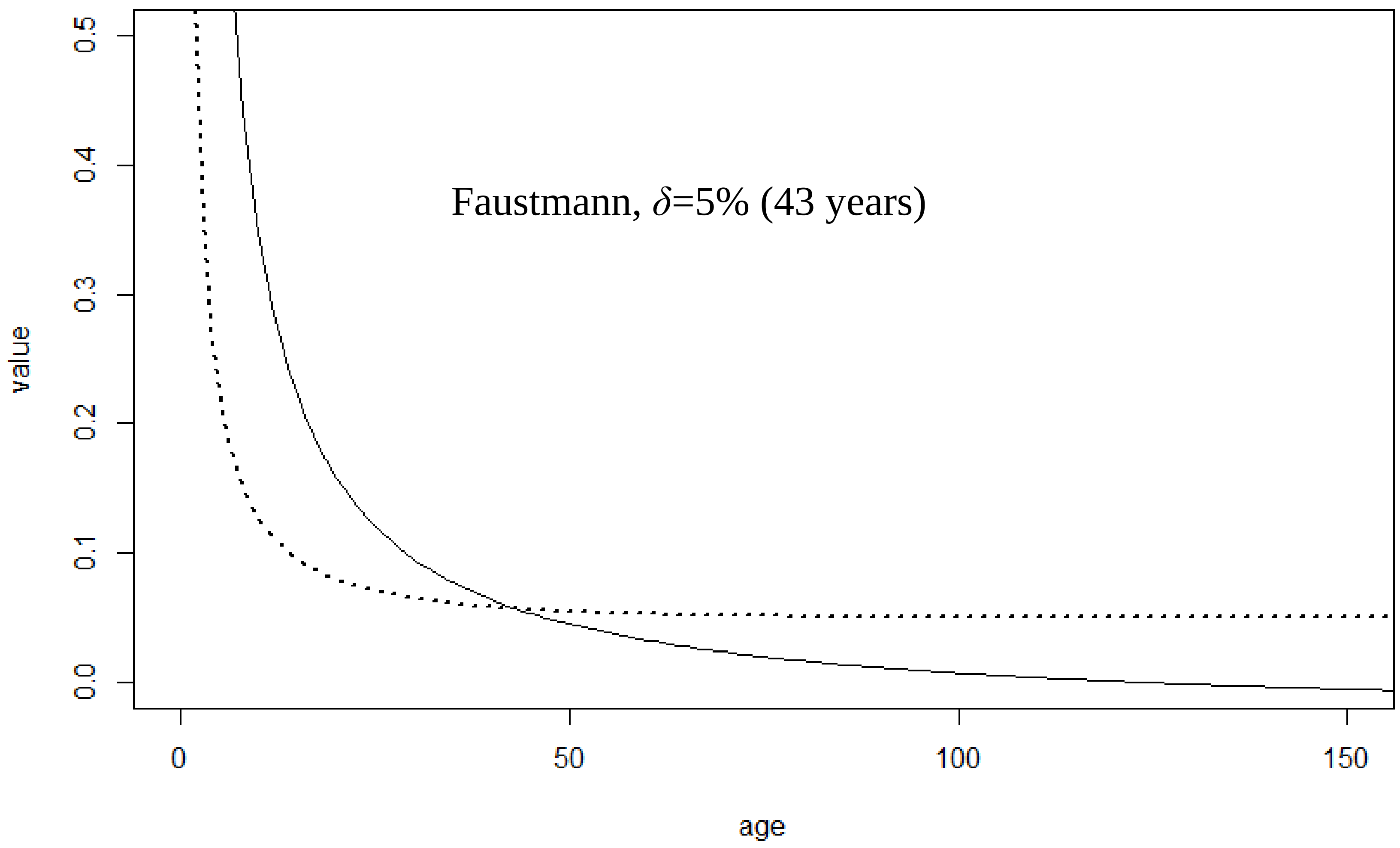
β = pickling factor ($0 \leq \beta \leq 1$);
γ = weight on timing of carbon fluxes (rate of discount on physical carbon);
d = decay rate of post-harvest carbon pools.

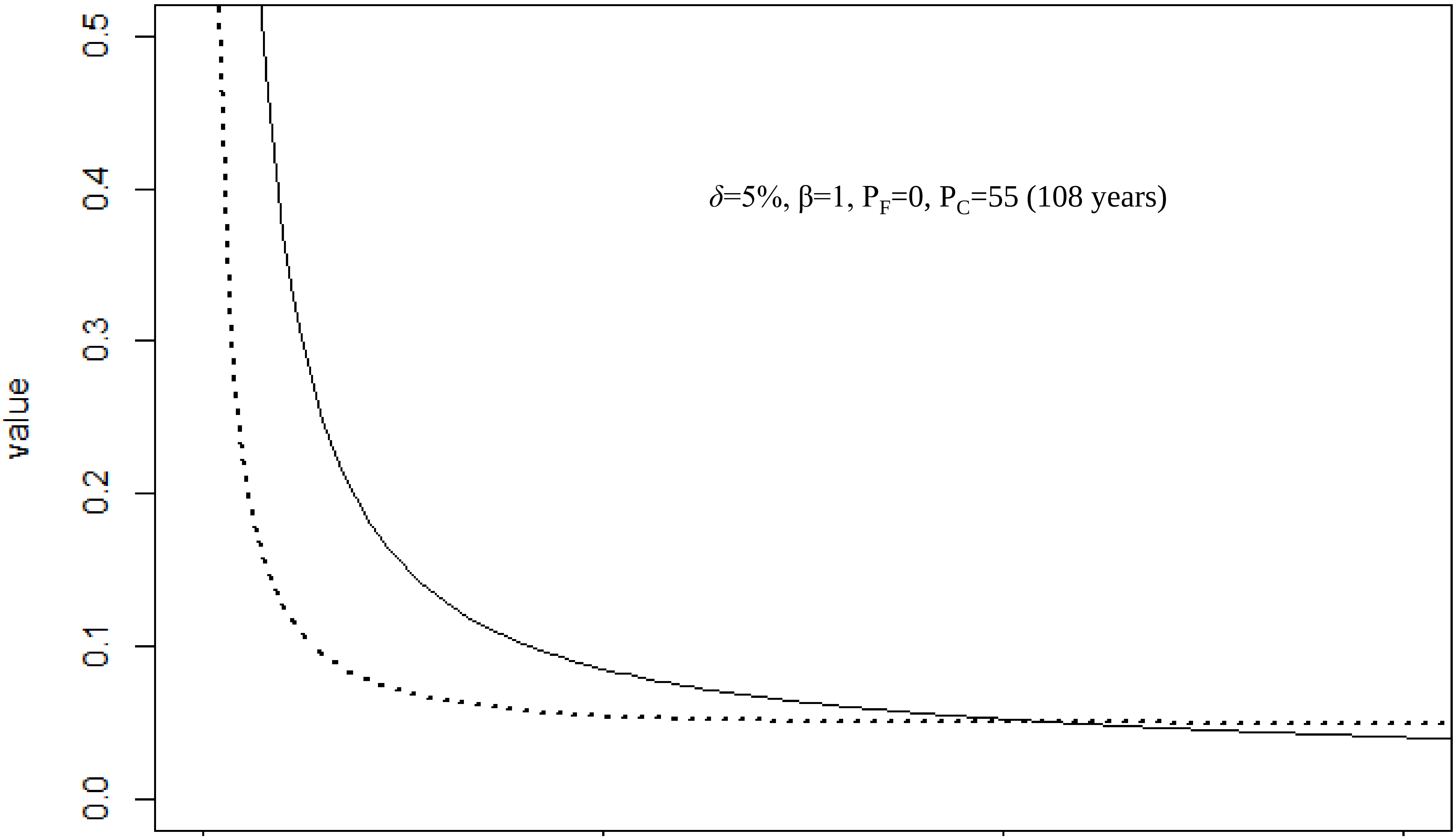
Various parameterizations

1. If $P_c = 0$, one gets the Faustmann rotation.
2. If γ=0 and d=0, then no decay of post-harvest wood products, no weighting of timing of carbon fluxes.
3. If γ>0 and d>0, $A = \alpha\beta P_c\left(1 - \frac{d}{\gamma + d}\right)$. This is the case in equation (1).
4. If γ=0 and d>0, $A = \alpha\beta P_c\left(1 - \frac{d}{\gamma + d}\right) = \alpha\beta P_c(1 - 1) = 0$.
5. If γ>0 and d=0, $A = \alpha\beta P_c$.
6. If the carbon price, P_c, increases faster than $\gamma \geq 0$, then there is incentive to delay tree planting which could lead to an infinite rotation age.

Growth Functions for BC Coastal Forests



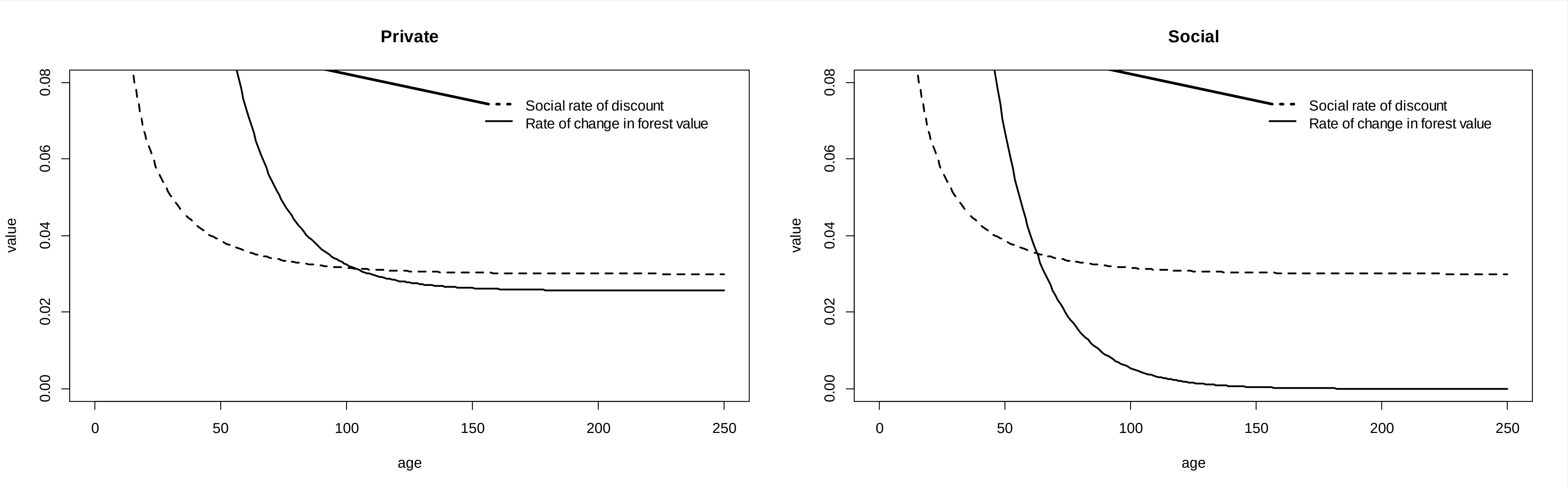

Faustmann, δ=5% (43 years)
value
0.0
0.1
0.2
0.3
0.4
0.5
age
0
50
100
150



value
0.0
0.1
0.2
0.3
0.4
0.5
δ=5%, β=1, P_F=0, P_C=55 (108 years)

(a) Rotation age=103 yrs; PTE=∞

(b) Rotation age=65 yrs; PTE=5.934 tCO_2



Private (no weight on carbon) vs Social Optimum (5% weight on carbon) for Gompertz Growth Function:
$\beta = \frac{1}{2}$, $P_F = \$150/m^3$, $P_c = \$200/tCO_2$, *decay rate* $= 0.0293$

Natural Disturbance: Wildfire

- Canada’s intended nationally determined contribution (INDC) for efforts to meet Paris targets: only ‘anthropogenic emissions and removals’ are considered, not carbon fluxes associated with natural disturbances.
- Studies have included natural disturbance to determine rotation age: van Kooten, Johnston and Mokhtarzadeh (*J of For Econ* 2019); Ekholm (*Forest Policy and Economics* 2020); Siebel-McKenna, Johnston & van Kooten (*Spatial Econ Analysis* 2020) .
- General approach: stochastic dynamic programming
- Conclusions from van Kooten et al. (2019)
  - Wildfire risk delays harvests as carbon prices rise, with less carbon stored in harvested wood products and more in the forest ecosystem
  - Increased risk of natural disturbance causes the landowner to harvest sooner.
    - Increased prevalence and severity of natural disturbance somewhat offsets the lengthening of rotation age that occurs when carbon is priced.
  - With disturbance, the total amount of carbon sequestered falls significantly, but some of this can be recovered through proactive planting of genetically modified (GM) stems that are more productive and less susceptible to disturbance

Natural Disturbance: Wildfire (cont)

Conclusions from Siebel-McKenna et al. (2020)

- Ignoring natural disturbances results in overestimation of carbon sequestration potential & underestimation of its costs. Could influence managers to forgo managing forests for carbon benefits at all.
- Ignoring natural disturbance risk in the establishment of baselines for carbon accounting may lead to situations in which forest managers find it difficult to generate carbon offsets, because carbon prices penalize emissions related to the harvesting and processing of HWPs, which, in turn, leads to reduced carbon-storage capabilities.
- As carbon prices increase, the amount of carbon sequestered in living and dead biomass (including soil) increases but plateaus at around a carbon price of $\$100/tCO_2$.
- Carbon pricing leads to less carbon stored in post-harvest wood products due to penalty of associated harvesting and processing.
- Carbon offset scheme intending to encourage carbon capture must carefully consider these opposing forces, even if the baseline considers the risk of natural disturbance.

Carbon Uptake Conclusions

- Tension exists between the social rate of time preference and the rate used to discount carbon values.
- A low discount rate that incentivizes early adoption of climate mitigation strategies leads to delayed afforestation, as does as rising carbon price.
- Choice of a growth function impacts rotation age and thus creation of carbon offset credits.
- Decay of post-harvest wood product sinks and carbon discounting affect the optimal rotation age and carbon offset credits that can be claimed.
- Despite an externality-correcting carbon tax, social and private forest rotation age continue to diverge.
- It may be unwise to lean heavily on forest carbon offsets for mitigating climate change.

5. Politics and corruption

- Principal-agent problem of forest carbon offsets
  - There is a cost of using forest carbon offset credits in lieu of CO_2 emission reductions
  - In addition to transaction costs, poor governance is an obstacle to creation of carbon offsets
  - There are many principal-agent layers between the supplier and demander of forest offsets
  - Purchasers of forest carbon offsets are often ignorant of the actual impact on climate mitigation

- Measurement

Principal-Agent Relationships and the Contracting of Carbon Offset Credits

Descending order of control over the effectiveness of CO_2 offsets

Principal	Agent	Description/Comment
Landowner	Land user / tenant / peasant (‘on-the-ground’)	Agent maximizes immediate net returns to land use; principal maximizes present value of net returns in long run. Contract could be informal or non-existent
Aggregator / Contractor	Landowner / farmer	Landowner and land user may be the same agent (as in developed countries). Some form of contract required to present for certification.
Certification Process: Certifier / ‘Gatekeeper’		Certifier and aggregator could be linked if governance structure is unable to ‘ring a fence’ around different aspects of a firm
Seller or Contractor	Aggregator	Seller/contractor and aggregator could be identical
Buyer	Seller	When purchasing offset credits, buyer trusts credits are legitimate and truly reduce atmospheric CO_2, whether true or not

Evaluation of 50 Carbon Offset Projects

Item	Number	Likely junk	Potentially junk	Lack information
Overall Carbon offsets (Mt CO_2)	50 (343)	39 (267)	8 (61)	3 (15)
Forestry & land use	23	20	2	1
Renewable energy	16	15	1	0
Chemical processes/industrial manufacturing	4	1	3	0
Household devices	3	2	0	1
Waste disposal	2	0	1	1
Other	2	1	1	0

Source: https://www.theguardian.com/environment/2023/sep/19/do-carbon-credit-reduce-emissions-greenhouse-gases?CMP=Share_AndroidApp_Other

Why projects were classified as likely or potentially junk

Guardian graphic. Source: Guardian/Corporate Accountability analysis.

Source: https://www.theguardian.com/environment/2023/sep/19/do-carbon-credit-reduce-emissions-greenhouse-gases?CMP=Share_AndroidApp_Other

Conclusion

- There is some ability to employ forestry activities to create carbon credits that offset emissions from fossil fuel burning.
- BUT society should recognize the limits to forestry activities in mitigating climate change; after all, there are other important nonmarket values of forests that should not be overlooked in pursuit of climate nirvana.

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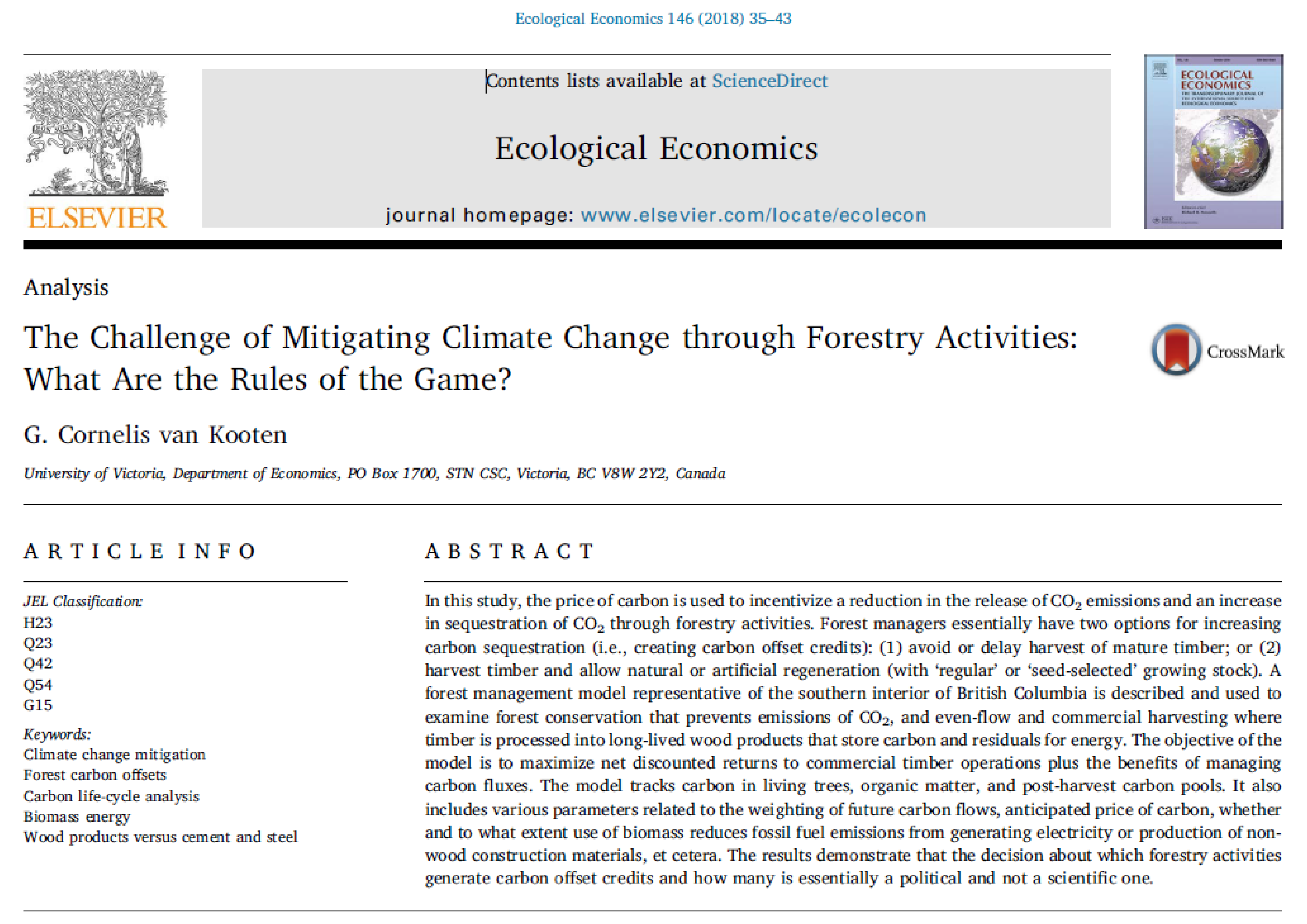
Quesnel Forest Management Model



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Analysis

The Challenge of Mitigating Climate Change through Forestry Activities: What Are the Rules of the Game?

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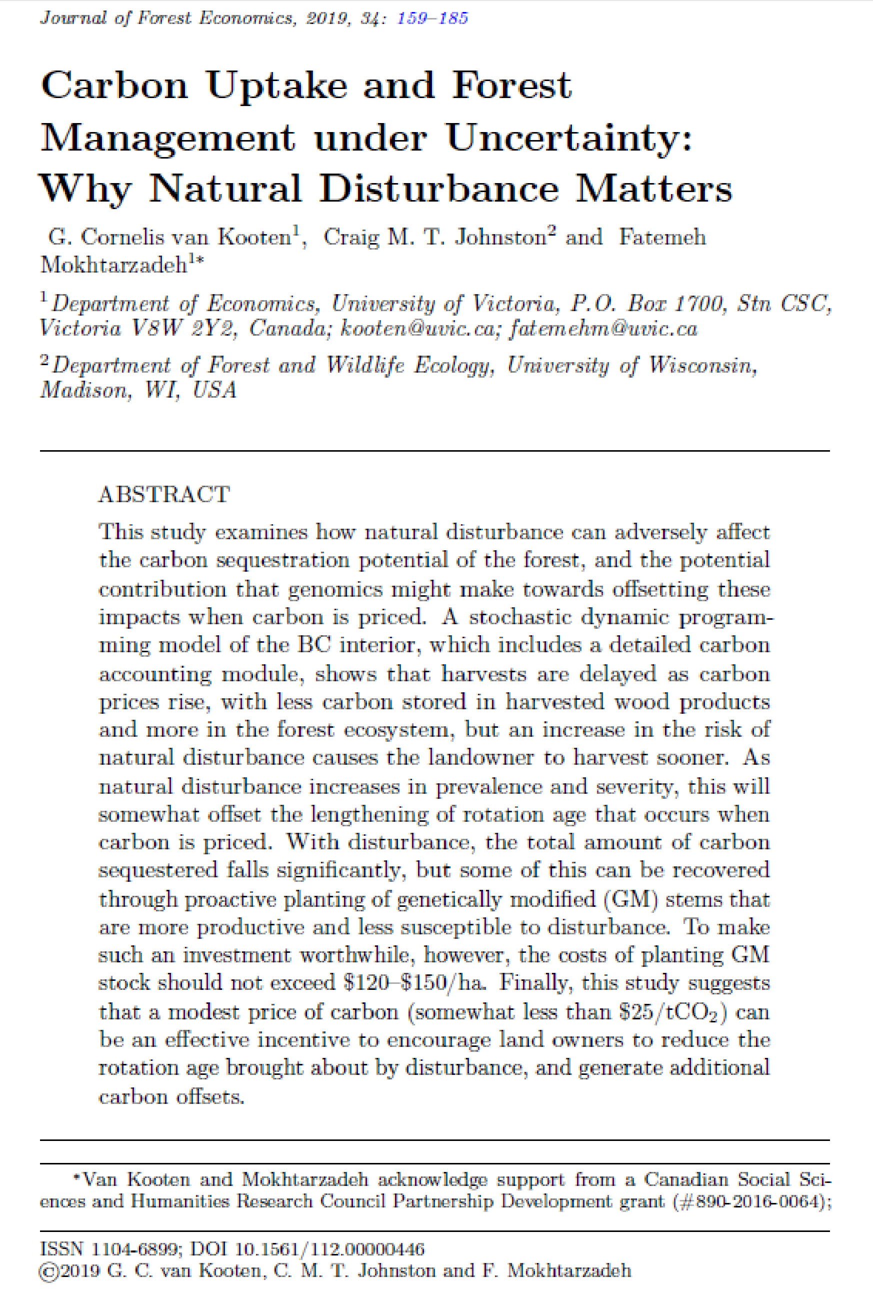
ABSTRACT

In this study, the price of carbon is used to incentivize a reduction in the release of CO_2 emissions and an increase in sequestration of CO_2 through forestry activities. Forest managers essentially have two options for increasing carbon sequestration (i.e., creating carbon offset credits): (1) avoid or delay harvest of mature timber; or (2) harvest timber and allow natural or artificial regeneration (with 'regular' or 'seed-selected' growing stock). A forest management model representative of the southern interior of British Columbia is described and used to examine forest conservation that prevents emissions of CO_2, and even-flow and commercial harvesting where timber is processed into long-lived wood products that store carbon and residuals for energy. The objective of the model is to maximize net discounted returns to commercial timber operations plus the benefits of managing carbon fluxes. The model tracks carbon in living trees, organic matter, and post-harvest carbon pools. It also includes various parameters related to the weighting of future carbon flows, anticipated price of carbon, whether and to what extent use of biomass reduces fossil fuel emissions from generating electricity or production of non-wood construction materials, et cetera. The results demonstrate that the decision about which forestry activities generate carbon offset credits and how many is essentially a political and not a scientific one.

Natural Disturbance and Carbon Uptake



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Carbon Uptake and Forest Management under Uncertainty: Why Natural Disturbance Matters

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ABSTRACT

This study examines how natural disturbance can adversely affect the carbon sequestration potential of the forest, and the potential contribution that genomics might make towards offsetting these impacts when carbon is priced. A stochastic dynamic programming model of the BC interior, which includes a detailed carbon accounting module, shows that harvests are delayed as carbon prices rise, with less carbon stored in harvested wood products and more in the forest ecosystem, but an increase in the risk of natural disturbance causes the landowner to harvest sooner. As natural disturbance increases in prevalence and severity, this will somewhat offset the lengthening of rotation age that occurs when carbon is priced. With disturbance, the total amount of carbon sequestered falls significantly, but some of this can be recovered through proactive planting of genetically modified (GM) stems that are more productive and less susceptible to disturbance. To make such an investment worthwhile, however, the costs of planting GM stock should not exceed \$120–\$150/ha. Finally, this study suggests that a modest price of carbon (somewhat less than \$25/tCO$_2$) can be an effective incentive to encourage land owners to reduce the rotation age brought about by disturbance, and generate additional carbon offsets.

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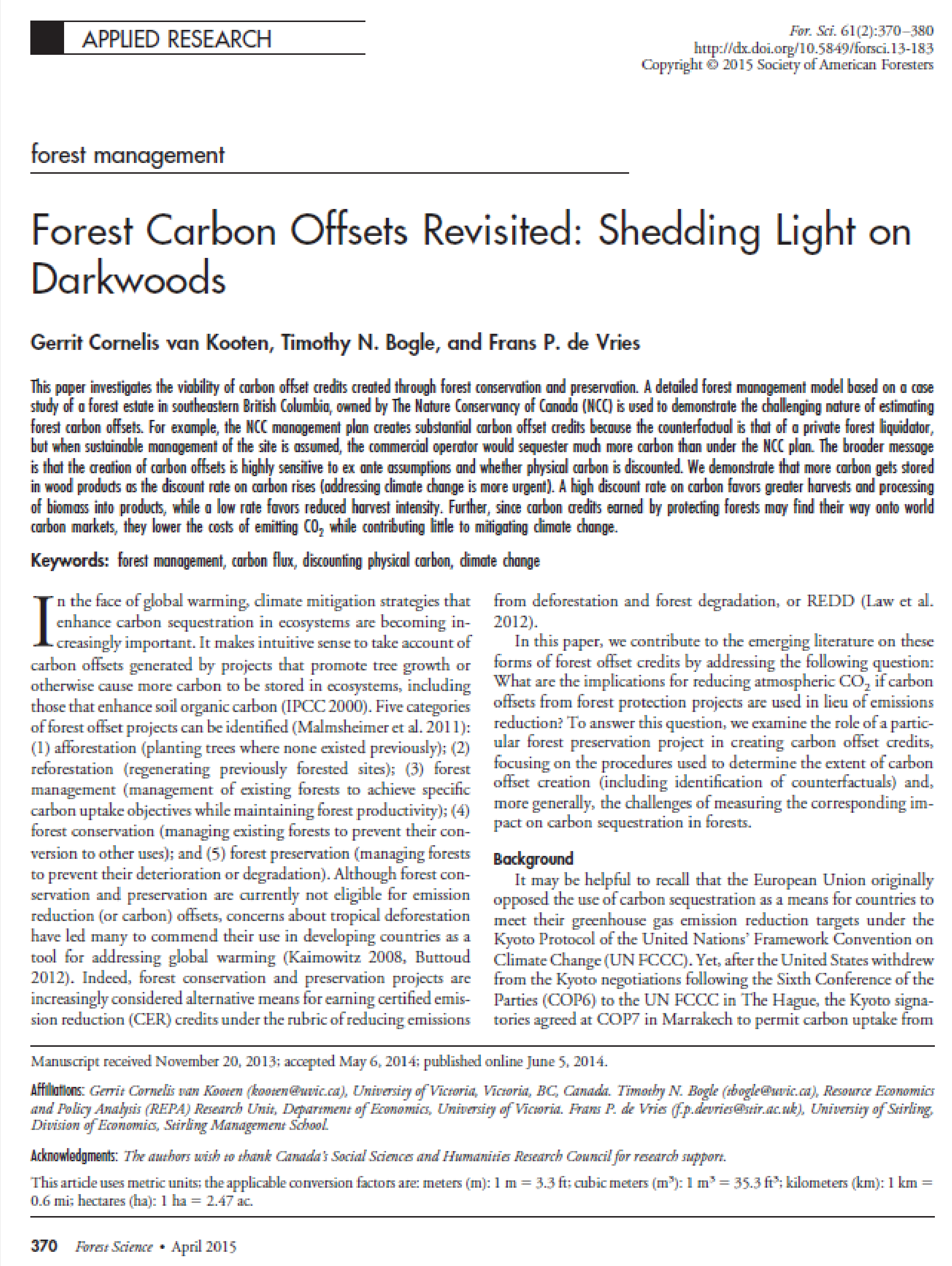
Forest Management and Creation of Carbon Offsets



APPLIED RESEARCH

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forest management

Forest Carbon Offsets Revisited: Shedding Light on Darkwoods

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This paper investigates the viability of carbon offset credits created through forest conservation and preservation. A detailed forest management model based on a case study of a forest estate in southeastern British Columbia, owned by The Nature Conservancy of Canada (NCC) is used to demonstrate the challenging nature of estimating forest carbon offsets. For example, the NCC management plan creates substantial carbon offset credits because the counterfactual is that of a private forest liquidator, but when sustainable management of the site is assumed, the commercial operator would sequester much more carbon than under the NCC plan. The broader message is that the creation of carbon offsets is highly sensitive to ex ante assumptions and whether physical carbon is discounted. We demonstrate that more carbon gets stored in wood products as the discount rate on carbon rises (addressing climate change is more urgent). A high discount rate on carbon favors greater harvests and processing of biomass into products, while a low rate favors reduced harvest intensity. Further, since carbon credits earned by protecting forests may find their way onto world carbon markets, they lower the costs of emitting CO_2 while contributing little to mitigating climate change.

Keywords: forest management, carbon flux, discounting physical carbon, climate change

In the face of global warming, climate mitigation strategies that enhance carbon sequestration in ecosystems are becoming increasingly important. It makes intuitive sense to take account of carbon offsets generated by projects that promote tree growth or otherwise cause more carbon to be stored in ecosystems, including those that enhance soil organic carbon (IPCC 2000). Five categories of forest offset projects can be identified (Malmsheimer et al. 2011): (1) afforestation (planting trees where none existed previously); (2) reforestation (regenerating previously forested sites); (3) forest management (management of existing forests to achieve specific carbon uptake objectives while maintaining forest productivity); (4) forest conservation (managing existing forests to prevent their conversion to other uses); and (5) forest preservation (managing forests to prevent their deterioration or degradation). Although forest conservation and preservation are currently not eligible for emission reduction (or carbon) offsets, concerns about tropical deforestation have led many to commend their use in developing countries as a tool for addressing global warming (Kaimowitz 2008, Buttoud 2012). Indeed, forest conservation and preservation projects are increasingly considered alternative means for earning certified emission reduction (CER) credits under the rubric of reducing emissions from deforestation and forest degradation, or REDD (Law et al. 2012).

In this paper, we contribute to the emerging literature on these forms of forest offset credits by addressing the following question: What are the implications for reducing atmospheric CO_2 if carbon offsets from forest protection projects are used in lieu of emissions reduction? To answer this question, we examine the role of a particular forest preservation project in creating carbon offset credits, focusing on the procedures used to determine the extent of carbon offset creation (including identification of counterfactuals) and, more generally, the challenges of measuring the corresponding impact on carbon sequestration in forests.

Background

It may be helpful to recall that the European Union originally opposed the use of carbon sequestration as a means for countries to meet their greenhouse gas emission reduction targets under the Kyoto Protocol of the United Nations' Framework Convention on Climate Change (UN FCCC). Yet, after the United States withdrew from the Kyoto negotiations following the Sixth Conference of the Parties (COP6) to the UN FCCC in The Hague, the Kyoto signatories agreed at COP7 in Marrakech to permit carbon uptake from

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This article uses metric units; the applicable conversion factors are: meters (m): 1 m = 3.3 ft; cubic meters (m^3): 1 m^3 = 35.3 ft^3; kilometers (km): 1 km = 0.6 mi; hectares (ha): 1 ha = 2.47 ac.